

Influence of sodium and potassium on morphological growth responses of *Ziziphus mauritiana* and *Syzygium cuminii* under controlled conditions



Irfan Ahmad¹, Muddassar Hussain*¹ Muhammad Asif¹, and Muhammad Haroon U Rashid^{1,2,3}

¹Department of Forestry and Range Management, University of Agriculture, Faisalabad, Pakistan.

²College of Forestry, Fujian Agriculture and Forestry University Fuzhou, 350002, Fujian Province, PR China

³Fujian Provincial College and University Engineering Research Center of Plantation Sustainable Management, Fuzhou 350002, People's Republic of China

Corresponding author: muddassarjutt112@gmail.com

Article Info

Abstract

Keywords:

Climate change, Sodium, Potassium, Salt stress, Semi-arid

Date:

Received: 01 January 2025

Revised: 27 January 2025

Accepted: 29 April 2025

Online: 30 April 2025

Published: 30 May 2025

Volume: 04 (01), 2025



Copyright: © 2025 by the authors. This article is distributed under the Creative Commons Attribution (CC BY) license, allowing for open access and sharing under specified terms and conditions. (<https://creativecommons.org/licenses/by/4.0/>)

Ziziphus mauritiana and *Syzygium cumini* (Black plum) are important trees of India and Pakistan, where poor irrigation practices are responsible for the soil salinity. Their study was conducted in the wire-house of the Department of Forestry and Range Management, University of Agriculture, Faisalabad, during spring 2019 to assess the growth of these two species against salinity. About 6 to 8-month-old seedlings of uniform size were used for the trial. Five NaCl salinity levels were developed artificially by maintaining their EC, such as T₀= Control without NaCl- salinity (EC 1.25 dSm⁻¹), T₁= EC 05 dSm⁻¹ with NaCl, T₂= EC 10 dSm⁻¹ with NaCl, T₃: EC 15 dSm⁻¹ with NaCl and T₄= EC 20 dSm⁻¹ with NaCl. The results showed significant differences across various salinity levels. The shoot length was recorded as the maximum in *Z. mauritiana* (131.62 cm) and *Syzygium cuminii* (96.846 cm) without salinity, but in treatment (T₄), where NaCl concentration was 20 dSm⁻¹, it was (33.98 cm) and (21.722 cm) respectively. Diameter was recorded as maximum without NaCl-salinity application in *Z. mauritiana* (5.374 mm) and *S. cuminii* (4.164 mm). The minimum diameter was recorded in T₄ i.e. (1.268 cm) and 4.144 cm. Similarly, all other parameters showed the same trend. Low K⁺ concentration was observed while higher Na⁺ in both species. *Z. mauritiana* is a moderately fast-growing species that showed luxurious growth in comparison with *S. cuminii* under saline conditions. It was concluded that *Z. mauritiana* is more tolerant the salinity as compared to *S. cuminii*.

1 Introduction

Ziziphus mauritiana and *Syzygium cumini* are important species in Pakistan and India that have major contributions to their economies and are used for many purposes such as medicine, fruit, forage, timber, firewood, etc (Rafiullah, 2006). The extensive use of soil decreases the productivity of agricultural land which leads to soil salinity and waterlogging. The growing of fruit trees on saline lands and waterlogged lands are very easy to grow as compared to agricultural lands. Tree species have special adaptability to accumulate salts and plants avoid their excessive accumulation because some plants excrete the salts and dilute them without disturbing the osmotic relations. The world half of the land is affected by salinity which is about 20% of the land (Agrawal *et al.*, 2013). The soil is affected by salt about 397 Mha and 434 million hectares of soil are sodic (FAO, 1973; Corbishley and Pearce, 2007). The area affected by moderate salinity was 1.758 Mha (10%) in Pakistan from the year 2001 to 2003. About, 0.637 million ha (4%) was moderately saline

*Email: muddassarjutt112@gmail.com

and 1.149 million ha (6%) was strongly saline (Corbishley and Pearce, 2007; Zaman and Ahmad, 2009). Soil salinity creates foremost issues in arid to semi-arid areas of Pakistan, particularly in the uphill side of northern areas and Indus regions. The salinization mechanism of soil is that soluble salts start to accumulate on the soil. The availability of soil water and water potential is reduced by a higher accumulation of salts near the plant's root zone (Arndt *et al.*, 2000) which causes decreasing water contents which is responsible for water loss at cell level and osmotic pressure. The Na and Cl ions are increased in the surroundings which affects the nutrient uptake of the plant by disturbing the ionic selectively permeable membrane through competitive interactions (Shiyab *et al.*, 2013). Soil salinity problem is a difficult physicochemicals properties of the soil in which different biological molecules i.e protein, free radical, carbohydrate, lipid, nucleic acid, hormones, free amino acid, mineral elements, and ions are included (Munns, 2002; Liu and Baird, 2004; Verma *et al.*, 2018).

Salinity responsible for the closure of stomata, decreases the photosynthesis process which enhances the absorption of activated oxygen species (AOS) i.e. hydroxyl radical (OH), superoxide radical, and H_2O_2 (Arzani, 2008). Salt stress disturbs the chlorophyll contents, enzyme kinetics, photosynthesis, membrane permeability, stomatal conductance, metabolites, and ionic concentrations (Garcia Sanchez *et al.*, 2002). The growth and development of Plants are affected due to the influence of ion selectivity membrane because salinity ions act on nutrient uptake by competing with plant roots, through a low-affinity system due to higher concentrations of exterior sodium prohibiting the accumulation of potassium and calcium (Grattan and Grieve, 1992). After all, the accumulation of potassium is a complex interaction with ions and roots that enhances the sodium concentration of plant leaves (Lloyd *et al.*, 1990). *Zizyphus mauritiana* is a most important and robust tree in arid to semi-arid areas and can grow effectively in these areas with arid to semiarid climates. Indian jujube *Zizyphus mauritiana* bears fruits that contain rich amounts of vitamin, B, A and C compounds (Pareek, 1983). *Z. nummularia* and *Z. rotundifolia* are widely planted for business purposes plantations because of their ability to tolerate salinity but limited information available on salinity tolerance process and mechanisms is not known (Pandey *et al.*, 1991). So, keeping in view the gravity of the issue present research work was conducted to evaluate the NaCl salinity tolerance of *Zizyphus mauritiana* and *Syzygium cumini* during initial growth stages, and various studies are conducted to familiarize with the salt tolerance in these species and physiological mechanism.

2 Materials and Methods

The purpose of the current research work was to find out the “Growth attributes of *Zizyphus mauritiana* and *Syzygium cumini* at different salinity levels”. Therefore a pot trial was established in the greenhouse of the Department of Forestry and Range Management, University of Agriculture, Faisalabad during spring 2019 to assess the growth of these two species against salinity. About 6 to 8-month-old seedlings of uniform size were used for the trial. The five NaCl salinity levels were developed artificially by maintaining their EC such as T_0 = Control without NaCl- salinity ($EC\ 1.25\ dSm^{-1}$), T_1 = $EC\ 05\ dSm^{-1}$ with NaCl, T_2 = $EC\ 10\ dSm^{-1}$ with NaCl, T_3 = $EC\ 15\ dSm^{-1}$ with NaCl and T_4 = $EC\ 20\ dSm^{-1}$ with NaCl. Before the development of salinity levels, soil samples were collected to ensure that there was no salinity was collected from the research area of the Department of Forestry and Range Management, University of Agriculture, Faisalabad. Air-dried the soil samples and passed them through a 2 mm sieve and evaluated for physico-chemical properties like EC, SAR, and pH (Table 1).

Table 1: Physico-Chemical Properties of the Soil

Characteristic	Value
Texture	loam
Sand (%)	36.45±0.53
Silt (%)	42.73±0.82
Clay (%)	22.62±0.75
Saturated Percentage (%)	28.00±1.82
Organic Matter (%)	0.81±0.23
pH	7.61±0.03
Electrical Conductivity (dSm^{-1})	2.49±0.41
Sodium Adsorption Ratio	8.68±0.39

2.1 Saturation Percentage (SP)

To determine the saturated percentage soil paste was dried at 105°C and SP was determined by using the following formula

$$SP = \frac{\text{Mass of soil} - \text{Mass of oven Dry Soil}}{\text{Mass of Oven Dry Soil}} \times 100$$

pH meter was used to measure the soil-saturated paste (Richards, 1954). The electrical conductivity of wet soil extracts (EC_e) a saturated soil paste extract was obtained with the help of a vacuum pump and a digital Jenway Conductivity Meter used to measure its electrical conductivity. Establishment of 25 seedlings of each species were selected to grown in pots. Tap water was used for irrigation in the whole experiment. The proportion of tap water is given in (table 2)

Table 2: Chemical Composition of Tap Water

Determination	Value	Unit
TSS	11.2	meL^{-1}
EC_e	1.02	dSm^{-1}
$Ca^{+2} + Mg^{+2}$	4.4	meL^{-1}
Na^{+}	5.8	meL^{-1}
Cl^{-}	1.2	meL^{-1}
CO_3^{-2}	Absent	meL^{-1}
HCO_3^{-}	8.00	meL^{-1}
SAR	3.92	$(mmol\ L^{-1})^{1/2}$
RSC	3.60	$mmol\ L^{-1}$

2.2 Determination of K^{+}

A flame photometer (Jenway PFP-7) was used for digested shoot samples to analyze the K^{+} . (Gee and Bauder, 1986; Hand Book 60, Method 5). The nutrient standard solutions and a standard curve were prepared instruments to be calibrated with a series of respective. The values are compared with the standard calibration curve and readings were obtained on the digest.

$$K^{+} (mg\ g^{-1}) = \frac{\text{Concentration from calibration curve (mg } L^{-1}) \times \text{dilution factor}}{\text{weight of digested samples (g)}}$$

2.3 Determination of Sodium

A flame photometer Jenway PFP-7 was used to determine the Sodium in the digested material after running standards of Na salt (Gee and Bauder, 1986; Hand Book 60, Method 5). The standard curves are made by calibrating the instruments with their representative nutrient standard solution. The values were compared with the actual concentration in the digest was obtained with the average calibration curve.

$$Na^{+} (mg\ g^{-1}) = \frac{\text{Concentration from calibration curve (mg } L^{-1}) \times \text{dilution factor}}{\text{Weight of the digested samples (g)}}$$

2.4 Parameters

Different Morphological parameters were studied during the experimentation i.e. Shoot length, No. of branches, Root length, Diameter, Shoot Fresh weight, No. Of leaves per plant, Root Fresh weight, Leaf area, Shoot Dry weight, Root dry weight, Sodium and Potassium concentration.

2.5 Statistical analysis

Statistical analysis was performed by utilizing the statistical software Minitab 2016 (Steel and Torrie, 1980)

3 Results

Various morphological parameters of both species were determined at different salinity levels are given in Figure 1. An evaluation of the mean was measured to determine morphological parameters indicated a gradual decrease with the boost of salinity levels in tree species ($p < 0.05$). The growth response of *Z. mauritiana* and *S. cuminii* species was recorded and also determine morphological attributes such as no. of branches, root length, diameter, shoot length, no. of leaves per plant, leaf area, shoot fresh weight, root dry weight, root fresh weight, shoot dry weight, sodium, and potassium concentration) were determined. The results showed significant differences against the salinity levels. The shoot length was recorded as the maximum in *Z. mauritiana* (131.62 cm) and *S. cuminii* (96.84 cm) without salinity but in treatment (T_4), where NaCl concentration was 20 dSm^{-1} , *Z. mauritiana* SL was observed in (33.988 cm) and (21.722 cm) respectively in both species (Fig.1).

Root length was measured at T_0 without NaCl-salinity was (45.39 cm) in *Z. mauritiana* and *S. cuminii* (37.462 cm). At T_4 , where NaCl concentration was 20 dSm^{-1} , trend remained same. *Z. mauritiana* (11.852 cm) and *S. cuminii* showed the minimum RL of (8.134 cm) at EC 20 dSm^{-1} in treatment T_4 . Diameter was recorded maximum without NaCl-salinity application in *Ziziphus mauritiana* (5.374 mm) and *Syzygium cuminii* (4.164 mm). The minimum diameter was recorded at 20 dSm^{-1} in *Z. mauritiana* (1.268 cm) and (4.144 cm) in *S. cuminii*, (Fig-1). Comparison of means of number of branches reduced significant decrease were observed in all salinity levels in both species ($P < 0.05$). The leaf area of *Z. mauritiana* (44.644 mm^2) was higher accordingly in control treatment without NaCl- salinity and in *S. cuminii* was (63.78 mm^2). The minimum leaf area value was measured at T_4 where NaCl salinity level was 20 dSm^{-1} . A significant decline was recorded in plant leaf areas 15 and 20 dsm^{-1} (Fig-1).

Ziziphus and Syzygium growth under salinity stress

Shoot fresh weight of *Z. mauritiana* was (750.08 g) without salinity application while at T₄ it was (277.64 g) where the NaCl salinity level is 20 dSm⁻¹ in *S. cuminii* it weighed (121.53 g) indicating a (Fig-1). The root growth is significantly affected at higher salinity levels (Fig-1).

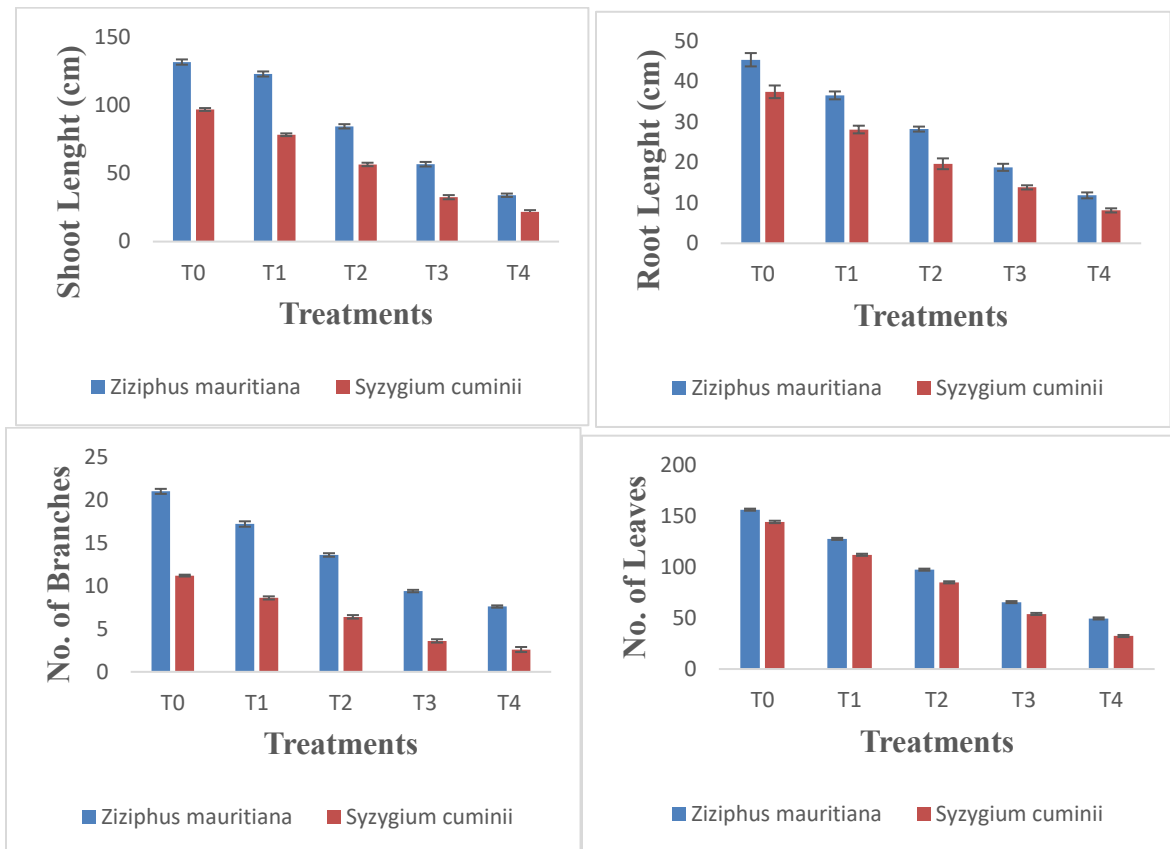


Figure-1. Effects of NaCl-salinity concentrations on morphological characteristics of *Ziziphus mauritiana* and *Syzygium cuminii*.

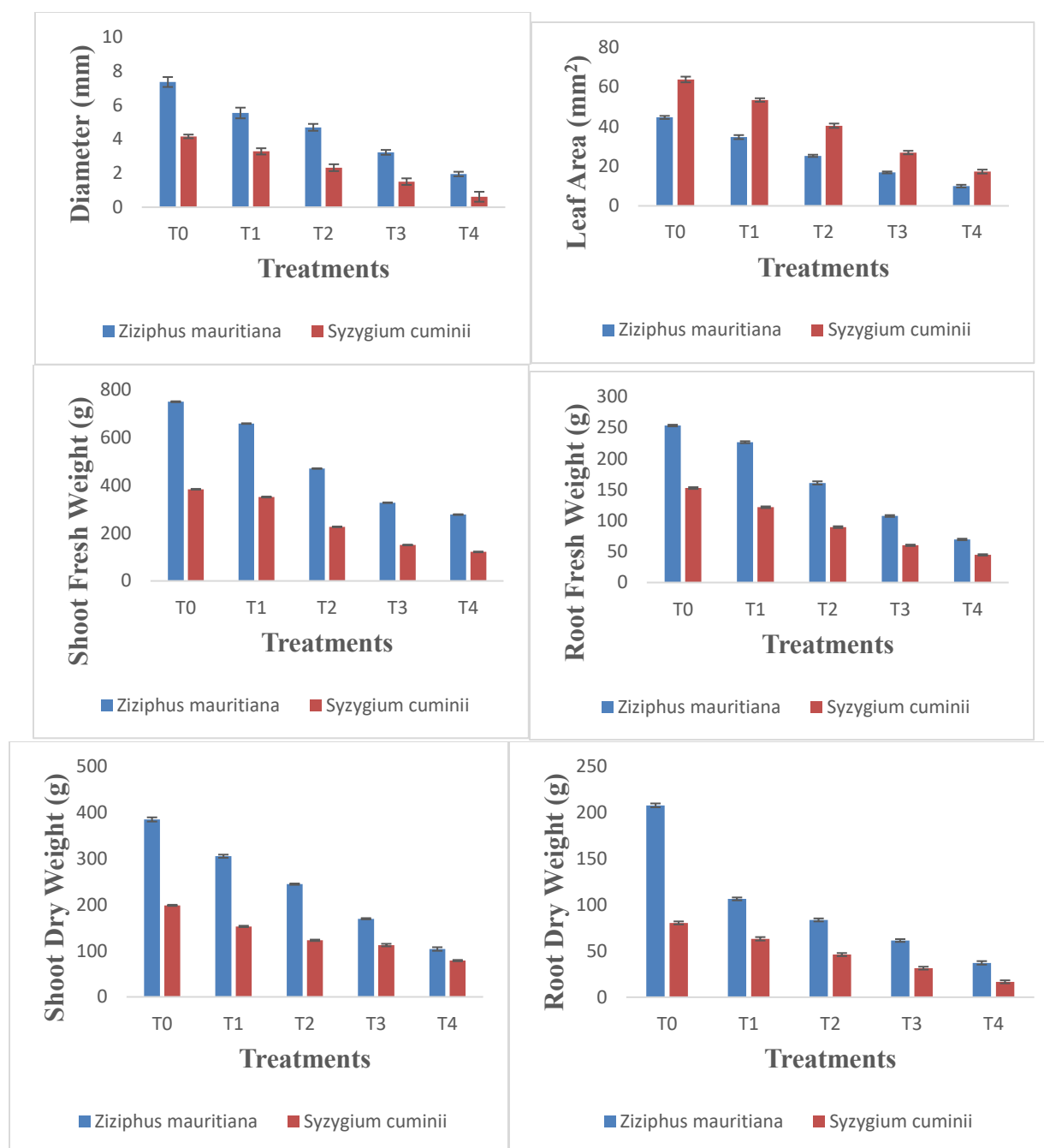


Figure-2. Effects of NaCl-salinity concentrations on morphological characteristics of *Ziziphus mauritiana* and *Syzygium cuminii*.

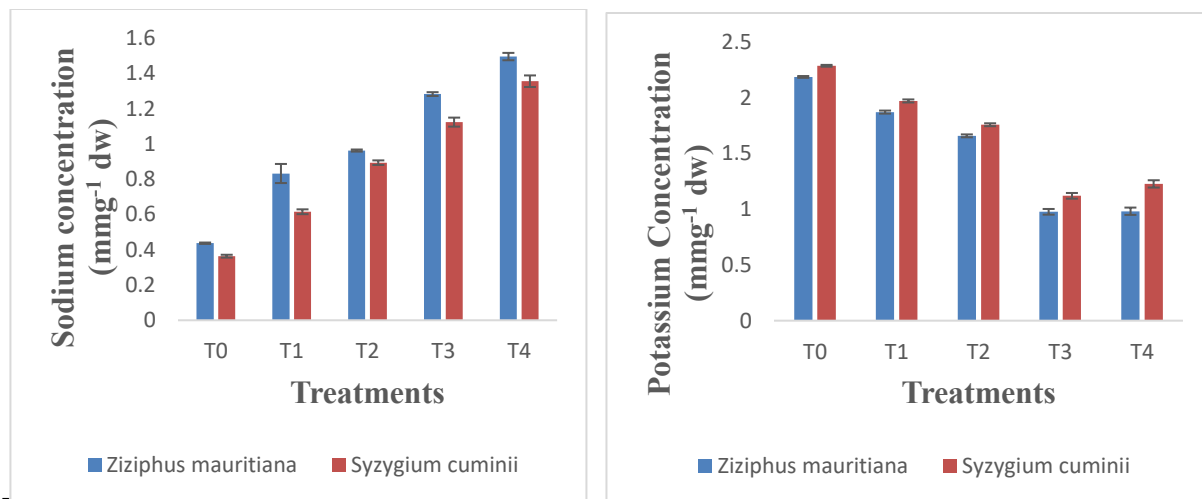


Figure. 3 Effects of NaCl-salinity levels on Sodium and potassium Concentration uptakes by *Ziziphus mauritiana* and *Syzygium cuminii* in leaves.

4 Discussion

The finding reveals that a significant decrease was observed in all salinity levels. The results indicate that all morphological parameters showed a significant decrease in both agroforestry tree species with the increases in salinity levels. Both tree species behave differently against all salinity levels however *Z. mauritiana* tolerates NaCl levels more as compared with *S. cuminii*. The finding reveals that salinity lowers the overall plant growth attributes i.e. leaf area, stem diameter, dry weights, plant height, shoot fresh and belowground parameters (root dry weights and fresh weight) however, the survival of both species was not affected in all salinity levels but a significant decrease was observed in biomass and findings are similar with various previous studies. The results demonstrated that *Z. mauritiana* and *S. cuminii* biomass was significantly decreased at higher salinity levels. (Chookhampaeng, 2011; Pulavarty and Sarangi, 2015) determine that the bamboo species survived against the salinity. The reduction in shoot length was observed by, Yousfi *et al.* (2007). The high deposition of salinity in the plant cell wall alters the metabolic pathways that reduce the cell wall elasticity and shoot length. The plant's secondary cell appears sooner and the wall becomes rigid decreasing the cell turgor pressure and efficiency. This process may make the plant shoot shorter the leaf expansion, leaf area, leaf emergence, and overall leaf growth (Cieeck and Cakirlar, 2002). However, plant shoot length is not only considered a good parameter to indicate the comparative tolerance of crop plants. The variation in the plant height is due to inherent variation in the species, however, many scientists still used plant shoot length as a parameter for comparison in salt-tolerant plant species. The root length under saline conditions was carried out by Marschner (1998). A decrease in root length due to salinity was also observed. RL of plants is considered an important parameter against the salinity tolerance of plants. (Alam *et al.*, 2014). This could be due to the effect of sodium and chlorine ions on root integrity and permeability, due to the changes of Ca^{2+} from the plasma lemma stopping the root length root and growth.

Hameed *et al.*, (2010) who was of the view that the metabolic pathway is changed by increasing salt concentration, which decreases the elasticity of cell walls and finally height of the plant. Results confirm the findings of former experiments i.e. stem diameter was reduced due to the decrease in turgor potential and extra metabolic energy by increasing salinity (Ashraf *et al.*, 1994; Qadir *et al.*, 1997). Teakle *et al.*, (2013) Seedlings with more shoot and root fresh weight were considered as good to cultivate under salt-affected soils. Salinity significantly reduced the growth production in seedlings Saqib *et al.*, (2013) found that the crop production of wheat was decreased under salinity stress. The decline in root fresh and dry weights under salinity stress was also observed in previous experiments (Abbas *et al.*, 2013). In general *Z. mauritiana* and *S. cuminii* species were good accumulator of sodium and potassium in their leaves. The maximum accumulation of sodium in *Z. mauritiana*. The potassium accumulation was decreased with the increase of salinity *Z. mauritiana* was a good accumulator of potassium without the application of NaCl. The Na and K^+ concentration was also observed. In conclusion, *Z. mauritiana* is a moderate fast-growing species that shows luxurious growth in comparison with *S. cuminii* under saline conditions. *Z. mauritiana* tolerated the salinity effects more effectively than *S. cuminii*.

Conclusion

The study concludes that *Ziziphus mauritiana* exhibits greater tolerance to salinity stress compared to *Syzygium cumini*. Growth parameters such as shoot length and diameter significantly declined with increasing salinity levels in both species, but *Z. mauritiana* maintained relatively better growth under saline conditions. Additionally, a higher sodium (Na^+) and lower potassium (K^+) concentration was observed in both species under salinity stress. Overall, *Z. mauritiana* is recommended for plantation in saline-affected areas due to its superior adaptability and growth performance.

Acknowledgment

We would like to gratefully acknowledge the staff of the Department of Forestry and Range Management, University of Agriculture Faisalabad, Pakistan, for providing support in the field work.

References

- Abbas, S.M., Akhtar, J., & Nasim, M. (2013). Salinity and drought interaction in wheat (*Triticum aestivum* L.) is affected by the genotype and plant growth stage. *Acta Physiology of Plant*, 35:2761-2768.
- Agrawal, R., Gupta, S., Gupta, N.K., Khandelwal, S.K., & Bhargava, R. (2013). Effect of sodium chloride on gas exchange, antioxidative defense mechanism and ion accumulation in different cultivars of Indian jujube (*Ziziphus mauritiana* L.). *Photosynthetica*, 51: 95-101.
- Alam, M.A., Juraimi, A.S., & Rafii, M.Y. (2014). Screening of Purslane (*Portulaca oleracea* L.) accessions for high salt tolerance. *The Scientific World Journal*, 10:1-12.
- Arndt, S.K., Wanek, W., Clifford, S.C., & Popp, M. (2000). Contrasting adaptations to drought stress in fieldgrown *Ziziphus Mauritiana* and *Prunus Persica* trees: Water relations, osmotic adjustment and carbon isotope composition. *Australian Journal of Plant Physiology*, 27: 985-996.
- Arzani, A. (2008). Improving salinity tolerance in crop plants: a biotechnological view. *In Vitro Cellular and Developmental Biology Plant*, 44: 373-383.
- Ashraf, M. (1994). Breeding for salinity tolerance in plants. *Critical Reviews in Plant Sciences*, 13: 17- 42.
- Çiçek, N., & Çakırlar, H. (2002). The effect of salinity on some physiological parameters in two maize cultivars. *Journal of plant physiology*, 28(12), 66-74
- Corbishley, J., & Pearce, D. (2007). Growing trees on salt-affected land. ACIAR Impact Assessment Series Report No. 51 July 2007
- FAO/ UNESCO. (1973). Irrigation, drainage and salinity- an international source book. London: Hutchinson.P. 510.
- Garcia-Sanchez, F., Martinez, V., Jifon, J., Syvertsen, J. P., & Grosser, J.W. (2002). Salinity reduces growth, gas exchange, chlorophyll and nutrient concentrations in diploid sour orange and related allotetraploid somatic hybrids. *Journal of Horticultural Sciences & Biotechnology*, 77, 379-86.
- Grattan, S.R., & Grieve, C.M. (1992). Mineral element acquisition and growth response of plants grown in saline environments. *Ecosystems and Environment*, 38, 275-300.
- Hameed, M., Ashraf, M., Ahmad, M.S.A., & Naz, N. (2010). Structural and Functional Adaptations in Plants for Salinity Tolerance. *Plant Adaptation and Phytoremediation*, 1, 151-170.
- Liu, X.N., & Baird, W.V. 2004. Identification of a novel gene, HAABRC5, from *Helianthus annuus* (Asteraceae) that is upregulated in response to drought, salinity, and abscisic acid. *American Journal of Botany*, 91: 184-191.
- Lloyd, J., Kriedemann, P.E., & Aspinall, D. (1990). Contrast between Citrus species in response to salinisation: An analysis of photosynthesis and water relations for different rootstockscion combinations. *Physiologia Plantarum*, 78, 236-46.
- Marschner, N.E. (1998). Salt tolerance of frost-resistant Eucalyptus. *New Forest*, 3:141-149
- Munns, R. (2002). Comparative physiology of salt and water stress. *Plant Cell and Environment*, 25: 239-250.
- Pandey, S.D., Pathak, R.K., & Dwivedi, R. (1991). Effect of sodicity and salinity levels on chlorophyll, free proline and amino acid content in ber leaves. *Horticultural Journal*, 4, 33-6.
- Pareek, O.P. (1983). Ber. ICAR Publication, Indian Council of Agricultural Research, New Delhi, India.
- Qadir, M., Qureshi, R.H., & Ahmad, N. (1997). Nutrient availability in a calcareous salinesodic soil during vegetative bioremediation. *Arid Soil Research and Rehabilitation*, 11:343-352.
- Rafiullah, M.R.M. (2006). Antidiabetic activity of some Indian medicinal plants. *Pharmacology and Biology*, 44:95-99.
- Saqib, M., Abbas, G., Akhtar, J., & Basra, S.M.A. (2013). Salinity tolerance potential of two acacia species at early seedling stage. *Pakistan Journal of Agricultural Research*, 50:683-688.
- Shiyab, S.M., Shatnawi, M.A., Shibli, R.A., Al Smeirat, N.G., Ayad, J., & Akash, M.W. 2013. Growth, nutrient acquisition, and physiological responses of hydroponic grown tomato to sodium chloride salt induced stress. *Journal of Plant Nutrition*, 36: 665-676.
- Teakle, N.L., Bazihizina, N., Shabala, S., Colmer, T.D., Barrett-Lennard, E.G., Rodrigo Moreno A., & Lauchli, A.E. (2013). Differential tolerance to combined salinity and O₂ deficiency in the halophytic grasses *Puccinellia ciliata* and *Thinopyrum ponticum*: the importance of K⁺ retention in roots. *Environmental and Experimental Botany*, 87, 69-78.
- Verma, S.S., Verma, R.S., Verma, S.K., Yadav, A.L., & Verma, A.K. (2018). Impact of salt stress on plant establishment, chlorophyll and total free amino acid content of ber (*Ziziphus mauritiana* Lam.) cultivars. *Journal of pharmacy and pharmacology*, 7(2): 556-559

- Yousfi, S. (2007). Effect of Salt on Physiological Responses of Barley to Iron Deficiency. *Plant Physiology and Biochemistry*. 45(5):309-14
- Zaman, S.B., & Ahmad, S. (2009). Salinity and Waterlogging in the Indus Basin of Pakistan: Economic Loss to Agricultural Economy. *Managing Natural Resources for Sustaining Future Agriculture Research Briefings. 1*: 4-8